LAYERED SENSING

Its Definition, Attributes, and Guiding Principles for AFRL Strategic Technology Development

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Foreword

The changing face of warfare and its migration from large state-on-state conflicts to Irregular Warfare is dramatically changing the requirements laid down by the Department of Defense (DoD) for acquiring and disseminating information. Creating "Situational Awareness" and information for all levels of "decision makers" from the President and Joint Chiefs to the Marine on the ground will require significant changes in acquisition, processing, and dissemination of information. This problem is tough when the ground, air, space, or cyber domains are hotly contested during wartime. Similarly, Homeland Defense and Civilian Governing bodies need different but equally ubiquitous information to make effective decisions regarding disaster response and relief activities in the face of Katrina-like natural disasters. These global changes have dramatically altered the need to expand the existing DoD technology base, to dramatically improve the quality and timeliness of acquiring, sorting, processing, and reporting information to improve effects based situation awareness.

In response to these and other doctrine changes, The Air Force Research Laboratory, the USAF's premier research arm, has established an urgent and focused, long-term strategy to improve DoD and USAF Situational Awareness technologies. This document helps to outline that strategy, by defining the context of a new technology construct called "Layered Sensing", which is defined as follows:

> "Layered Sensing provides military and homeland security decision makers at all levels with timely, actionable, trusted, and relevant information necessary for situational awareness to ensure their decisions achieve the desired military/humanitarian effects. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of "tailored effects"."

Although Irregular Warfare is a big "near term" driver to "Layered Sensing", **make no mistake** – "Layered Sensing" attributes will be essential at winning the next highly contested conventional war. Furthermore, as we rapidly understand and acquire these capabilities, we need to assure our "near peer" adversaries are denied these same "Layered Sensing" capabilities.

This report fully defines the attributes and context of "Layered Sensing" and thoroughly describes its implications for driving AFRL research. It is a **must read** for our AFRL Scientists and Engineers as well as our external stakeholders and customers at all levels, and has been circulated in draft form throughout the technical directorates at the request of Mr. Sciabica, AFRL Executive Director. This white paper represents a vital "first construct" from which we must organize and execute our future research activities beginning within the Sensors Directorate (AFRL/RY), and cross-cutting across our entire AFRL research portfolio.

Finally, AFRL/RY recognizes that this document represents a living, evolutionary construct that will have the flexibility to change and adapt to new concepts of sensor and platform modality. It is expected to be periodically reviewed, revised, and re-released as the concept evolves. Our "Layered Sensing" journey begins with this first bold step.

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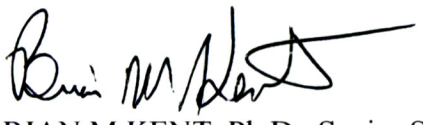
"Layered Sensing" is succinctly defined by the following:

> "Layered Sensing provides military and homeland security decision makers at all levels with timely, actionable, trusted, and relevant information necessary for situational awareness to ensure their decisions achieve the desired military/humanitarian effects. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of "tailored effects"."

This construct will serve Air Force Research Laboratory (AFRL) extremely well as it transforms its focus and research programs to successfully tackle some of the most complex and important technology problems facing the United States Air Force. AFRL has the honor and rare privilege of receiving the charter to provide our war fighters with affordable, war winning technologies. As an organization, the importance and daunting challenges ahead of us have been defined. The deep thinking part is behind us. It's time to get to work.



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Section 1 - Introduction and Background – The Need for "Layered Sensing"

1.1 The changing nature of Irregular Warfare and Its Impact on the USAF Mission

The nature of warfare has drastically evolved in the last sixty years. Beginning with the collapse of the Soviet Union, which effectively ended the "cold war", warfare throughout the world has morphed away from massive force-on-force conflicts (or threatened conflicts) sponsored by nation states, to regional, local, and transnational conflicts often with no discernable state connections, or known ties to purely non-state entities. From narco-terrorists to religious fundamentalists, the nature of conflicts has moved strongly in the direction of mass terrorism, whereby civilian populations and symbols of national power become the targets, and the objectives of war become centered on achieving conquests of minds and ideas versus conquests of territory. This change in the nature of warfare has had a dramatic impact on the application of national force in international conflicts. Furthermore, the traditional forces of national defense, made up of the Army, Navy, Marines, and Air Force, no longer have a clear picture or mandate on how to fight this new type of transnational anarchy. One thing is certain, however; it is utterly changing the way the Armed Forces of the United States will need to acquire, use, process, and share information to develop the requisite situational awareness needed to make appropriate and correct decisions about the application of force in future "Irregular Warfare" conflicts.

The United States Air Force recently dedicated an entire new volume of official Air Force Doctrine to the subject titled "Irregular Warfare", ([1] AF Doctrine 2-3 dated 1 August 2007), page 1 defines "Irregular Warfare" as "*a violent struggle among state and non state actors for legitimacy and influence over relevant populations. Irregular Warfare favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities in order to erode an adversaries power, influence, and will*". Furthermore, Irregular Warfare has some foundational statements (again from AFDD-2-3) which include:

- Irregular Warfare is not a lesser-included form of traditional warfare. Rather, Irregular Warfare encompasses a spectrum of warfare where the nature and characteristics are significantly different from traditional war.

- Traditional warfare and Irregular Warfare are not mutually exclusive; both forms of warfare may be present in a given conflict.

- Military power alone cannot bring decisive victory.

- The Air Force must be prepared to simultaneously conduct irregular and traditional warfare operations.

- Legitimacy and influence are the main objectives.

- The Air Force provides valuable and unique capabilities in Irregular Warfare. In many cases, these capabilities provide flexible and persistent options for dealing with Irregular Warfare challenges by providing a less intrusive force that can respond quickly and improve commanders' overall situational awareness.

- In any phase of operation, the Air Force can be employed with varying degrees of intensity and visibility.

- The protracted approach that adversaries may use in Irregular Warfare requires a long-term strategy for victory. Winning a protracted war is all about winning the struggle of ideas, undermining the legitimacy of a competing ideology, addressing valid grievances, reducing an enemy's influence, and depriving the enemy of the support of the people.

- In irregular operations, commanders should understand that the application of military force is in support of other instruments of national power, and that traditional joint force organizational relationships may not be as effective for irregular operational environments.

- Each Irregular Warfare contingency is different, and no single planning template can be applied to every operation

1.2 The Changing Role and Complexity of Intelligence, Reconnaissance, and Surveillance in Irregular Warfare: Prior to the rapid evolution of Irregular Warfare (or forth generation warfare), the Air Force had created multiple Intelligence, Reconnaissance, and Surveillance (ISR) assets, most of which were designed and used to monitor the behemoth Cold War forces of the former Soviet Union. We wanted to know where their missiles, ships, planes, and tanks were at all times. From space, the US monitored internal communications, photographed forces and facilities, and kept an ever watchful eye on nuclear launch sites. Our CIA, NRO, DIA, and USAF analysts reviewed data, analyzed results, and reported the same through each of their stovepipe channels. These collective "guesses" were merged by the National Security Council, and in an overall sense, the analyses were more often right than wrong. Usually, the US could determine what the Soviet Union was doing based on when and where the forces were moved. The timescale of crisis events during the Cold War were measured in days and weeks, and the ISR and situational awareness tools that DoD and the USAF developed worked magnificently within these constraints.

Irregular Warfare is changing everything. In Kosovo, information about air strikes was not relayed solely by an Integrated Air Defense System; it was aided by a series of US and foreign cell phone calls to complement early warning. In hotspots throughout the world, roadside bombs and IED's are placed in hours or minutes. Suicide bombers execute missions in hours, minutes, even seconds. Even in the US, an airliner was hijacked, and intentionally crashed into the World Trade Center in under an hour, before authorities were even aware what happened. The whole concept of slow, deliberate periods of assessment and reporting to develop "situational awareness", which worked so

well in the Cold War, was utterly incapable of responding to this new threat and timescale.

To make the problem of generating situational awareness even more difficult, Irregular Warfare now must address the culture and context of information. The cultures and ideologies involved with IW conflicts through the world are nowhere close to monolithic. We have international organized crime "Narco-terrorists" working in South America, Maoist fighting in Peru, Tamil Tigers in Sri Lanka, and no less than four or five diverse religious fundamentalist organizations spread throughout the Middle East. Each of these entities has different social and cultural influences, values, and approaches to their IW conflicts. This puts even more demand on the need to understand information in the context of the source, the parties involved, and their intentions.

While we are discussing Irregular Warfare, one may logically ask "will future conventional 'near-peer' conflicts also drive these changes in both doctrine and technical approach"? The answer is an emphatic "YES!". Tomorrow's near peer adversary likely will launch attacks in the Air, Ground, Space, and Cyber domains, perhaps simultaneously. The approach to provide the Situational Awareness to anticipate, interact, and appropriately react to all potential intelligence scenarios of the next conventional fight are also supported in the Layered Sensing Attributes to follow. But make no mistake – what is important in Layered Sensing in the irregular fight applies equally to counter attacks on the seas, in the air, on the ground, in space, or cyber.

1.3 Current Air Force Doctrine 2-9 (November 2007) on Intelligence, Surveillance, and Reconnaissance (ISR): As the USAF grapples with the need to adjust their approach and tactics to effectively combat both the conventional and Irregular Warfare scenarios, they also understand that our approach for defining and conducting ISR must also adapt. Recently, with the release of AF Doctrine 2-9 [2], the entire concept of ISR has been revised. As with IW, by quickly examining this document and its foundational statements, we can begin to appreciate how the Air Force Research Laboratory "Layered Sensing" construct fits within the future of ISR. From AFD2-9: **"***The goal of intelligence, surveillance, and reconnaissance (ISR) operations is to provide accurate, relevant, and timely intelligence to decision makers. The Air Force best achieves this goal through effective employment of ISR capabilities, and by capitalizing on the interoperability existing among our ISR systems, as well as nontraditional sources, to create synergy through integration*." Other foundational ISR doctrine statement includes"

- Air Force surveillance and reconnaissance assets are not inherently strategic, operational, or tactical in nature; they can be used to gather information to meet requirements at all levels of warfare (conventional or irregular – ed.).

- Intelligence products must enable strategic, operational, and tactical users to visualize the operational environment systematically, spatially, and temporally, allowing them to orient themselves to the current and predicted situation to enable decisive action.

- Planning and direction of ISR operations start with the identification of needs for intelligence regarding all aspects of the operational environment. (ed. Intelligence has the connotation that it is developed behind a green door and not available to those walking down the street – Layered Sensing isn't as we've defined it, focused only on generation of intelligence)

Looking over these statements, it is clear what the USAF decision makers want – "accurate, relevant and timely information". Yet knowing the pace of Irregular Warfare, or of administrating a civilian area (either in theater or the homeland) the definition of a "decision maker" is far broader than previously envisioned. The "decision maker" might be responsible for applying (or restraining) deadly force, mitigating tensions, exercising diplomacy, assisting civil authorities, feeding military or civilian personnel, transporting people or supplies, treating injuries, preventing a pandemic, responding to a natural disaster, and so forth. What is needed by the "decision maker" is far greater than "accurate, relevant, and timely information". It is accurate, relevant, and timely *situational awareness* that allows the "decision maker" to make the right (appropriate) choices in as many diverse situations as possible. Many would suggest that situational awareness is only achieved in the minds of the human users, it can't be generated by the ISR enterprise – the ISR enterprise only extracts from the environment the data necessary for consumption by the human to become aware of the situation. Many would suggest that machine to machine connections cannot achieve awareness. Whether we are willing to let such machine-to-machine calculations pull triggers (kinetic or cyber) is yet to be seen.

1.4 Mission of the US Air Force and Air Force Research Laboratory: The mission of the United States Air Force is "*to deliver sovereign options for the defense of the United States of America and its global interests -- to fly and fight in Air, Space and Cyberspace*". The "sovereign options" and "Defense of the United States of America" includes all ranges of conflicts, including those previously discussed. As the USAF continues to rapidly morph from a post cold war force structure, and adapt to the new IW challenges faced in places like Afghanistan and Iraq, the USAF leadership looks to the Air Force Research Laboratory to help provide future capabilities that will allow them to execute their mission. How does AFRL fit in? The Air Force Research Laboratory mission is to **"***Lead the discovery, development, and integration of affordable war fighting technologies for our air, space and cyberspace force."* AFRL is the organization responsible for developing our future technical capabilities that will *keep* the USAF fully combat capable and ready to execute its mission in both the near and far term.

Recognizing the rapidly changing technological landscape and the evolving nature of Irregular Warfare, AFRL recently completed a 30-year strategic plan [3] titled "Air Force Capabilities Based Science and Technology Strategy 2030". This document comprehensively lays out the AFRL technology thrusts which will be pursued to enhance the USAF's capabilities to adapt to the strategic challenges of conventional and irregular warfare. In this strategic plan, AFRL lays out its technology vision:

- "The Air Force Capability-Based Science & Technology Strategy is built upon the Air Force Science and Technology Vision—anticipate, find, fix, track, target, engage, and assess- anything, anywhere, anytime. "

In order to realize this vision, AFRL realizes it must develop the science and technology to pursue three fundamental capabilities for Air Force war fighters. Once again, from the AFRL Strategic Plan:

(1) *Universal situational awareness (USA)*: The achievement of situational awareness is an essential prerequisite for action – whether on the battlefield or in international relationships. A number of technology enablers are essential components of delivering this capability. Ultimately, it must be based on "defense in depth" incorporating information from air, space and cyber sensing assets. (ed. The reader is cautioned, however, to limit analogies of these "physical sensing systems" with the hierarchical description of the battle space we are producing through the employment of a "layered sensing" architecture. To be effective in achieving Universal Situational Awareness, we need to peel back the information onion that hierarchically describes the battle space, and the "layers" of "layered sensing" are associated with the information onion that completely describes the battle space in terms of the physical entities embedded there and the intents and implications for our blue force missions, including fused knowledge delivery and forensic capabilities.) In the mid-term, space and cyber situational awareness will be essential capabilities to develop, in addition to providing the ability to synthesize and interpret vast quantities of sensory and context information for decision makers. Lastly, the newest addition in our quest for complete situational awareness is the ability to understand and eventually anticipate psycho-cultural adversarial behavior.

(2) *The ability to deliver precision effects*: Our tactics and strategies have changed over the past two generations, from one of airborne delivery of massive quantities of weapons – to one of precision engagement of specific adversaries. It will become even more critical in the future as tensions rise or conflicts ensue, that our Air Force be able to provide a broader range of precision effects to support options for Combatant Commander and National leadership. Technology strategies being pursued include low collateral damage precision weapons with directed energy and cyber capabilities, unmanned and increasingly autonomous vehicles of all sizes, and hypersonics to support rapid global engagement.

(3) *The enduring ability to access and survive in the battlespace*: All of the military capabilities that might be brought to bear in conflict are of little value if forces cannot gain access to the battlespace – whether it is air, space, or cyberspace. Each domain has its unique challenges, and in air at least, the Air Force *currently* has no peer. Continuing emphasis against emerging air anti-access measures will be complemented by pursuing technologies to support four additional thrusts: a) on-demand access to space; b) sustaining war fighting capabilities; c) cyber security, forensics and assured battlespace networks; and d) self protection including the next generation stealth technology.

Clearly, all of AFRL's active and passive threat suppression technologies fall under this category as well.

These technology vectors *clearly followed* the recommendations of a recently completed Defense Science Board (DSB) 2006 Summer Study on 21st Century Strategic Technology Vectors (Volumes I and II) dated February 2007 [4]. In the letter summarizing the conclusions of this document, the DSB advocated the need to "develop four operational capabilities and their enabling technologies that can support the range of future military missions. In identifying these capabilities, the report defines broadly, to include tools enabled by the social sciences as well as the physical and life science." These capabilities include "(1)…to gain a deeper understanding of how individuals, groups, societies, and nations behave, then use this information to improve the performance of US forces…and shape behaviors of others in pre-, intra-, and post-conflict situations; (2) (develop)…greatly enhanced capabilities to observe people, things, and activities in urban and other tough terrains, and to record and recall the data; (3) …extract actionable information hidden in massive data much more rapidly than is done today and (4)…producing effects – offensive and defensive, kinetic and non-kinetic, lethal and non-lethal—tailored rapidly to the circumstances in order to achieve the desired and avoid the counterproductive." The authors go on to say "A key enabler to all these capabilities is the availability of ubiquitous, secure, reliable, rapid connectivity among all sources and users of information". Perhaps most importantly, the authors further state "…and cut in half the time it takes to field major systems".

There is no question that the AFRL strategic goals are in alignment with the DSB study, and that all are in alignment with the evolutionary AF Doctrines on Irregular Warfare and ISR.

1.5 – The Duality of the Homeland Defense Scenario: Before concluding this introduction, it is important to understand that everything discussed to this point regarding warfare, defense, and the need for more timely, accurate and critical situational awareness applies *equally* to Homeland Defense scenarios. Consider three classes of natural disasters, all from recent US History. Everyone remembers the 2005 Category 5 Hurricane Katrina, which destroyed much of New Orleans, and waylaid communities in 4 Gulf States. Consider modern versions of other historical disasters, including the 1906 San Francisco earthquake, which toppled buildings that subsequently burned in a 4-day uncontrollable firestorm. More recently the disastrous "night of the tornadoes", April 3-4 1974, when 148 viciously strong tornadoes pasted widely spread communities in twelve states, including Xenia, Ohio. Add to these natural disaster scenarios is the ever present possibility of another terrorist induced "9/11-like" Weapons of Mass Destruction (WMD) event.

Clearly the same civilian "decision makers" (Governors, Mayors, City Managers, Police and Fire Chiefs) have to make quick decisions in order to save the maximum lives and start effective relief operations. Fire and police authorities, first responders, hospitals and their staffs, national guardsmen, need to *precisely* know where to go first, and what areas and people are in the most distress. As with the military, civilian authorities desperately

need the same critical situational awareness. What is envisioned and understood by AFRL is that the *nature* of the specific situational awareness needed by military and homeland security personnel may differ slightly, yet the sensors and subsystems related to our "Layered Sensing" architecture will apply with near equality.

1.6 – The "Layered Sensing" Construct – A Key Element in the unifying implementation of the AFRL Strategic Plan: The introduction and background provided above lays out the fundamental challenges facing the USAF today. Clearly, the Air Force Doctrine is rapidly evolving to acknowledge the constantly changing landscape of global warfare, and its potential to impact the execution of the Air Force mission. In addition, the USAF understands that "traditional views" of ISR need to adapt, and new capabilities need to be acquired. In response AFRL, and its component Directorates are working together as never before, to define and execute the AFRL Science and Technology Vision. The strategic plan presents an opportunity to develop a unifying construct which pulls together an executable architecture which makes it possible to execute the A&T vision. That construct is called "Layered Sensing", and its definition and execution will drastically improve the Air Force's ability to execute its mission in the future.

Before proceeding to define "Layered Sensing", and its most important attributes, we begin the next section by introducing the "Layered Sensing Leadership Group", and describe the methods and deliberations that led to the development and ultimate refinement of this new construct.

Section 2.0 – Layered Sensing and its Attributes

2.1 The Layered Sensing Leadership Group: With any endeavor, it is virtually impossible with the limitations and ambiguities of the English language to put together a short yet definitive statement on any subject. Yet at some point, coalescing about a single definition, and understanding, in detail, the various interpretations of that definition goes a long way in reaching a common understanding of a profound and wide reaching construct. The term "Layered Sensing" first began to evolve within the Sensor's Directorate in the early summer of 2006, and soon became widely referenced. Although frequently referenced, there were concerns that individual briefers tended to use the term narrowly, while AFRL and Sensor Directorate leadership tended to interpret the term very broadly. For this reason, Sensors established a "Layered Sensing Leadership Group" (LSLG) to help formally define "Layered Sensing", establish and describe its detailed attributes, and use the output of the intellectual exchange to develop the core of this very white paper. The LSLG consisted of many S&E's drawn from the various AFRL branch and division technical experts, the directorate senior scientists and senior planners, Core Technical Competency (CTC) leaders, and cross cutting program managers. The LSLG Charter (Appendix A) defines the objectives for the LSLG and is summarized below.

- LSLG Objectives: The Sensors Directorate created a vision for Layered Sensing that has received support across AFRL and Air Force leadership as well as the Scientific Advisory Board. While there have been a number of research efforts addressing aspects of the Layered Sensing challenge, the LSLG needs to fully define the Layered Sensing Concepts and pull together all related Focused Long Term Challenges (FLTC) and AFRL/RY Core Technical Competencies (CTC) efforts into operationally relevant demonstrations to help better define the Layered Sensing architecture for the war fighter. (Note the FLTC and CTC technical planning and execution will be discussed in Section 3.3). The purpose of the LSLG was to provide this framework for the Sensors Directorate with the goal of collaborating with all relevant AFRL technical directorates who shares both an interest in and responsibility for AFRL's execution of Universal Situational Awareness (USA).

In order to begin to organize and align the Sensor Directorate's investment portfolios with the long term AFRL 2030 strategic plan, our Core Technical Competencies (CTC's) and Focused Long Term Challenge (FLTC) roadmaps need to be anchored around the "Layered Sensing" construct. The first step of the process was for the LSLG to define "Layered Sensing", and fully describe its attributes.

2.2 Layered Sensing Definition: After a long and spirited debate, the LSLG reached consensus on defining "Layered Sensing" as follows:

- *"Layered Sensing provides military and homeland security decision makers at all levels with timely, actionable, trusted, and relevant information necessary for situational awareness to ensure their decisions achieve the desired military/humanitarian effects. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of "tailored effects"."*

There is a lot to this short paragraph, and its components deserve to be examined in more detail. Let us disassemble the definition and see why this wording was chosen over other potential definitions.

(1) "**Layered Sensing provides…":** In the end, **"**Layered Sensing" (LS) is effects based. It is "delivering" a product, and that product is "situational awareness". We do that by acquiring, sorting, prioritizing, and displaying the data or information from which the human (or machine) will generate Universal Situational Awareness, in order to produce a desired military or humanitarian outcome.

(2)"**…military and homeland security decision makers...:** This section defines that the "decision makers" are the ultimate customers of the LS product. Interestingly, AF Doctrine 2-9 on ISR states (pp3) that the "decision makers" are a "diverse set of consumers, to include national agencies, geographic, functional, or service components; and unit level decision makers". Yet AFD 2-9's definition of a "decision maker" is defined far too narrowly to be relevant in many of the situations foreseen by AFRL. In Irregular Warfare situations, the decision maker could be the platoon Sergeant in an urban fight, or the Marine Lance Corporal flying a mini UAV. The "decision maker" could be an A1C maintainer trying to decide whether to "maintenance ground" an F-22 to repair a problem or simply turn the jet for the next mission. In the homeland security situation, as previously discussed, the "decision maker" could be a Police Captain, an ambulance driver, or a Doctor trying to administer care across a tenuous and widely fractured information network. The bottom line is that AFRL foresees the "decision maker" to be ubiquitous and at any level in the chain of command. Since decisions must be made in hours or minutes, the concept of centralized chain of handoffs becomes wholly untenable in rapidly fluid crisis situations.

(3) **… with timely, actionable, trusted, and relevant information necessary for situational awareness…**: The term "situational awareness" is frequently a catch all description for knowing everything and all the time. Some may imply this translates to total omnipotent knowledge. What AFRL understands is that it is not important to know everything, only the information that is *relevant.* AF ISR

Doctrine 2-9 (pp10) refers to Situational Awareness as "Predictive Battlespace Awareness (PBA)", and further defines it as a "multi-dimensional understanding of the battlespace in time, space, and effect". Again, AFRL feels that the definition of PBA is far too restrictive, especially if it is limited to solely military terms. "Situational Awareness" is a state of knowledge whereby the individuals who must operate within the "situational sphere" must understand the most important ("Relevant") information, that the information is correct and uncorrupted ("trusted"), that the information will allow the affected parties to take appropriate action ("actionable") and it arrives "in time" for that action to have the desired effect ("timely"). It is interesting that AFDD 2-9 also references "timely", "relevant" and "secure – our 'trusted'" when describing PBA.

It is easy to create examples of how lower level "decision makers" need exquisite situational awareness (SA). A HUMINT estimate might indicate that there are insurgents within a several block region of Fallujah. The Marine soldiers assigned to find them are briefed, and have that situational awareness. Yet this information only marginally helps them if they want to arrest the insurgents at 2 am in the morning, yet end up waking up fifty innocent Iraqi families in the process of looking for the right house. However, if a USAF Predator spots the insurgents going into <u>one</u> particular house, and these same Marines – the low level "decision makers" - get that situational awareness to tell them <u>which</u> house, their job is infinitely easier and safer. This could only occur, however, if the Layered Sensing construct allowed the "low level USAF Predator Operator" to quickly and accurately convey his Situational Awareness to the foot soldiers. This would likely only happen if the Predator operator had foreknowledge that there was a foot soldier patrol in pursuit of the insurgents he was tracking in the first place, i.e. he needs Army SA of intent *in reverse*.

Of course, the conventional fight produces information for higher level decision makers. How many ships are in the straits of the conflict? What types and where are they located? How many aircraft are in the air, and which ones belong to us and our adversary? All of this coarse information would have to be winnowed down so the single aircraft pilot is told where to go and what to shoot at. In some cases, the shooter (say an F-35) might provide the track and cue for another aircraft (an F-22 or F-15) to take the shot. Since you want to "counter" the "near-peer" layered sensing attributes, we need to also develop and execute "counter efforts" to deny this information to our adversary. Again, conventional warfare will quickly learn how vital *our* layered sensing architecture is to winning a "near- peer" fight, and why *denying* this capability to the "near-peer" is also of paramount concern.

In the homeland (Katrina) example, think of the huge knowledge gaps that were created after the hurricane struck. Without lights, power, or cell phones, National US authorities within FEMA had no idea what was happening within the Super Dome, the Convention Center, and on the many roofs of homes inundated with water. Had early helicopter responders been properly trained and equipped with

the correct sensing equipment and infrastructure to ship information, much more timely, and accurate information could have been used to dispatch the requisite help needed to these critical city regions within hours instead of days.

(4) … **to ensure their decisions achieve the desired military/humanitarian objectives…**: This section is almost self explanatory. In the example above, if the foot soldiers were sent a day later, the insurgents are gone. Not only were they not arrested (an undesired military effect), those same insurgents just blew themselves up in the market place the next morning killing 85 innocent people (an even more undesired military effect). In humanitarian cases, like the 911 disaster, hospitals in New York City executed plans based on disaster scenarios, to set up "Triage Centers", which quickly screen victims in order to have the desired humanitarian effect of saving the lives of those most likely to survive if treated. Again, using the Katrina example, if airlifted supplies of food and clean water had been brought hours sooner to the Superdome and Civic Centers, a large part of the post Katrina suffering would have been alleviated and the populace would not have reacted as it did.

(5) … **Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities…:** This short sentence outlines some of the technology embodiments which will make Layered Sensing a reality. The technologies will certainly include various sensor systems, including audio, visual, chemical, biological, radio frequency, microwave, x-ray, infrared, ultraviolet, X-ray, acoustic, and so on. There will be sensors for power systems, cyber systems, and human systems. Some of these sensors are simple devices and will work on a stand alone basis, with their own power and ability to communicate. Your cell phone is a sensor, especially if it has a camera and microphone. Other sensors will be sophisticated, and may operate from a soldiers backpack or helmet; a car, truck, or tank; a small unmanned aerial vehicle; or a large manned fighter or bomber; the sensor may even reside in space. When a sensor is an integral part of a platform that is moving or contains many other sensors, we call that a sensing system. In order to make use of all these sensors, we need infrastructure. This infrastructure is not simply the electrical (or chemical) power for the sensor. The infrastructure includes how to move the "sensed state" or "data" from the sensor itself to the "decision maker". This movement of data must be so seamless and so ubiquitous that neither the sensor nor the user of the data even notices. Infrastructure involves communications, storage, retrieval, and analysis, and ultimately leads to the "exploitation capabilities". This "exploitation" goes beyond a simple foreign intelligence connotation. It means taking the data and information *and figuring out what the data or information means and what should be done with the information"*. Properly exploited information leads one to "actionable information" which produces "designed military/humanitarian effects.

(6) …**to generate that situation awareness and directly support delivery of "tailored effects":** Reemphasizing the product, it is all about producing desired tailored effects. The identification of who or what we want to target must be assured and the information produced must be of "engagement quality" to allow Air Force Leadership to deliver sovereign options for the defense of the US and its Global Interests, whether it be to drop

a weapon, pick up a downed Airman, or deliver international disaster relief. Similarly, the Homeland Security Executive needs to achieve certain tailored effects in a crisis, including the delivery of food, supplies, medical care, and temporary housing. The product of layered sensing, in the end, provides the necessary situational awareness that ultimately is exploited for a purpose, and that purpose is to produce a specific, tailored effect.

2.3 The need to identify the attributes of Layered Sensing: Like any other generalization, "layered sensing" is a high order description of a sensing architecture that helps produce actionable situational awareness. To be "actionable" and to achieve "desired effects", the architecture must be able to seamlessly pass appropriate information to a targeting device and/or a weapon (in a military scenario) or to a hospital/first responder (in a civilian disaster scenario). In a sense, "Layered Sensing" is a capability taxonomy described at its most general level, and will ultimately be the linkage to the needs of the warfighter.

By itself, the definition of "layered sensing" is insufficient to describe what sub-capabilities or technologies are going to be required to achieve such a high level capability. For this reason, the Layered Sensing Leadership Group (LSLG) took the additional liberty of carefully examining the "attributes" associated with layered sensing. These "attributes" then became the multi-dimensional axes by which the taxonomy of AFRL's investment in Sensor Technologies will be measured against. This process will begin in early 2008, when existing CTC's and FLTC programs are measured against the attributes to identify "gaps" in technology development. A "gap analysis" will then make adjustments to the investment areas, and the progress of the technologies will be continually measured against the "attributes". One can see that getting the "attributes" identified and well defined in their own right is equally critical to the success of layered sensing.

2.4 Layered Sensing Attributes: The Layered Sensing Leadership Group ultimately selected twelve "attributes" to supplement the definition of "Layered Sensing". As further potential attributes were considered beyond this dozen, further discussion generally showed that one could build taxonomy back to one of the original dozen attributes. Therefore, let us proceed to identify each of the attributes in turn. The italicized statement in quotes following each attribute is the group's agreed upon definition of that attribute. Additional sentences beyond the quotes will elaborate, when necessary, on certain aspects of the attribute.

2.4.1 Persistent Coverage: "*Unblinking eye and omnipresent ears. The ability to provide surveillance and reconnaissance of an area or region in any domain (cyber, air, space) with a revisit rate consistent with mission and information requirements*."

The unblinking eye and omnipresent ears is a physical analogy with our own sense of sight and sound. But the analogy goes far beyond these simple senses. We will be "looking" into cyberspace, meaning sensor systems tied to computer domains and electromagnetic spectrums. We will be "listening" with electronic support sensors. There

will be a need to "sniff" for chemical, nuclear, and biological agents. The "surveillance and reconnaissance of an area or region in any domain" means the system must be scalable to address whatever the requirements of the "decision makers" could span. The "region or domain" could be a specific country, a continent, a city, or a specific computer network, and can occur in peacetime or in time of war, going back to the three "A's" of the S&T Vision – "… anything, anytime, anywhere".

2.4.2 Wide Area Coverage: "*A deployable and scalable system that can surveil local/theater/global-level areas of regard and rapidly focus on a specific area(s) of interest with a resolution based on the decision makers information demands while maintaining coverage of the area of regard.*"

In a military scenario, the concept of surveilling local/theater/global areas of regard is fundamentally embedded in current ISR doctrine. We need to watch cities within Theaters (Bagdad, Kurkuk, Kabul), individual countries (Iraq, Iran, North Korea, Afghanistan), all the while watching the oceans and Eurasian continents for ballistic missile launches. During a conflict or a crisis, while watching these areas, we need to "zoom in" on the action. We might want to see a specific street in Bagdad…image a specific ship on the ocean … monitor for nuclear traces in the pollution emissions from a specific North Korean plant. All the time, while zooming in, we cannot take our unblinking eye off the aforementioned regions. *Again, "Layered Sensing" will be vital to both Conventional and the Irregular fights ahead.* In civilian scenarios, our "global areas of interest" may include integrated weather models for severe storm effects prediction, or knowing the owners, cargos, and nationality of inbound civilian freighters and airliners. Homeland areas of regard could be as small as a street or individual building where a civilian hostage crisis or criminal activity is taking place.

2.4.3 Assured Global Access: "*The capability to access both cooperative and denied areas across all operating domains (including cyber). Elements of the Layered Sensing system of systems in denied domains must be survivable.*"

This attribute seems very self-evident, but the second sentence is extremely important. If our sensor architecture and subsystems must survive in denied domains, it is clear that our "cyberspace" initiatives must include a very robust Electronic Warfare/Electronic Attack/Electronic Support and Electronic Protection technology portfolio. This clearly includes threat suppression technologies. For example, AFRL's developmental persistent ISR "Angel Fire" system today could not survive in denied airspace without many changes. A future "Angel Fire"-like system must survive in denied airspace. If we can't place our sensors where they're needed to provide situational awareness, the USAF will have large gaps in their knowledge for effective decision making.

2.4.4 Engagement Quality Information: "*Information exploitation provided to the decision maker with the requisite precision, confidence, tracking, context, and where required cross-cueing, to provide him/her with the situational awareness necessary to execute the best decision/course of action. This can range from targeting of a kinetic/non-kinetic weapon to rapid delivery of humanitarian aid.*"

This attribute directly addresses the "desired effects" of layered sensing and assures that the actionable information can actually be executed. It means once we have decided, based on sensed and processed information, what "needs" to be done, if that "what" includes targeting a weapon on a city, a building, or even an individual, the "hooks" are in the layered sensing architecture to provide the targeting information to the weapon in the proper machine-to-machine format. This includes things like Combat ID, Automatic Target Recognition, and so forth. At the same time, in a disaster or homeland defense scenario, the item "targeted" is probably not a weapon at all. It is more likely akin to a humanitarian food drop, or deploying medical or law enforcement personnel exactly where they're most needed. Perhaps, due to infrastructure damage, it means knowing precisely where to reroute power to reestablish a national power grid during a blackout, when a portion of the grid is disabled due to a natural or terrorist induced event.

2.4.5 Timeliness: "*System responsiveness to support quality decision making information early enough in the decision cycle (including the ability to anticipate) to allow the appropriate decision maker adequate time to determine and execute appropriate action*."

There is an old expression that says "they wrap fish in yesterday's newspapers". Timeliness is all about getting the information in time to make a difference. Figuring out that Pearl Harbor was going to be attacked on December 8th based on sensed intelligence was too late. Finding out about "9-11" on "9-12" was also too late. If we had figured out, why several Arabic speaking males were learning how to "*fly"* airliners instead of how to "*take off and land*" airliners, perhaps some dots could have been connected that may have averted 9-11. The "anticipate" part of this attribute will be hard, but research must be applied to the subject to make it feasible in the future.

2.4.6 Trusted Sensing: "*Protocols and systems that establish trust between elements of the Layered Sensing architecture to ensure data is accurate, uncorrupted, and precludes exploitation by adversaries*."

Cyber warfare is one of the most vexing, elusive, and potentially dangerous of all our future threats. In an age where information can be stolen or easily altered, the need for "trusted sensing" cannot be overstated. It is so easy to modify videos and photographs with commercial software, that many courts won't accept such evidence unless an impeccable trail of documentation exists proving its authenticity. If we are shipping information around the Global Information Grid (GIG), we need to know what sensed information that is received was not modified or manipulated in the process. Offensively, the USAF needs to learn to find and exploit adversarial "GIG"-like networks. We must protect our own data, and deny the adversaries their data. The next Cyber War has already started and we must be expected to fight it, every day, every hour, every minute, and every second, from this time forward. The ultimate success of our homeland and military infrastructure depends on it.

2.4.7 Information Triage: "*The efficient identification of the most relevant pieces of information needed by the decision maker out of the volumes of collected data.*"

Information Triage is the idea to separate sensed information into three stacks; important, not important, or not sure. But we still don't know if the "not sure" contains a relevant piece of information, or what the priority might be in the "important stack". Consider an example. Anyone who subscribes to the Sunday New York Times understands information triage implicitly. In this mountain of a paper (…all the news that fits…) is an internet-placed "help wanted" advertisement for an explosives expert, with a phone number or email address that resides outside the US. Does the requester work for a mining company? (..a legitimate request) or some shady mid-eastern private holdings company (a red flag?). Could that information be sorted and identified as important and relevant? Another example is finding out that a potential high value human wanted by military or civilian authorities is driving a particular car with a known license plate. Where is the car – within the city limits of a Bagdad or New York City? The "Layered Sensing" architecture will be collecting more information than is almost imaginable. Part of the architectural design must be to learn to efficiently sort out the wheat from the chaff – or more likely the needle in the haystack while still being "timely". One promising research approach may be to research the nature of information itself to vastly reduce the sensor storage and processing requirements. A stop light camera is used to catch red-light runners. Suppose the sensor could also be designed to distinguish from a "red light" violator versus an actual vehicle collision. In the former case, the ticket is mailed at the convenience of the city. In the accident case, the sensor automatically calls the police and ambulance. This means the sensor would have to sort out the behavior "qualia" of a "normal red-light runner" versus an "abnormal red light runner" that causes a collision. AFRL is beginning some very exciting research topics in the area of understanding information "qualia", which may be one way to address the enormous demands of information triage.

2.4.8 Robust, Agile and Adaptable: "*Incorporation of autonomic sensing (self-aware, self-forming, self-healing, self-assessing) characteristics into sensors, and networks that allows them to reflexively optimize themselves based on intentional, inadvertent, or predicted changes to the sensor/network enterprise/environment. This includes bandwidth capability to support the transfer of information.*"

Building on the last example in the last attribute, it would be technologically possible to put a camera at every New York City street corner. Who, however, would be hired to watch all the monitors? Who could afford to? Therefore, sensors deployed within layered sensing must have as many autonomic functions as possible, and be appropriately networked. Such networks must balance "rigidity and strict taxonomy" with flexibility and reconfigurability. In addition, as sensors are lost due to malfunction or deliberate destruction, the layered "system-of-systems" architecture must robustly adapt and rebuild capability in response to the changes. Finally, you can't run a fire hose through a soda straw. Every sensor deployed in the layered sensing architecture must have the requisite network backbone or bandwidth necessary to transfer its functional data. Absent infinite

bandwidth, sensors may be trained to recognize when to report certain events, as discussed in 2.4.7.

2.4.9 Spectrum Dominance and Control: **"***Layered Sensing exploits observable quantities in RF, EO, acoustic, chemical, nuclear, biological, cyber, behavioral, and cultural dimensions through overt or covert observations*."

In the 1956 Hungarian revolution, the Soviet Union's invasion of Hungary began after they totally denied access to the electromagnetic spectrum. Their chaff and high power jammer coverage was supremely effective; none of the elements of the rebellion could communicate internally, while external countries couldn't use RF ESM sensors to effectively monitor what was going on until well after the Soviet Union's invasion was finished. More recently, Estonia and Latvia's national government and economic activity was literally halted with a crippling cyber attack. These are important historical lessons in spectrum dominance. In the future, "spectrum dominance" becomes ever more critical. Research into these areas also must consider entirely new areas of concern encompassing the behavior or cultural dimensions. The actions of our adversaries and our reactions must frequently take these factors into account. Understanding the motives and operations of our adversaries can only be achieved by understanding the behavior and cultural dimensions, which will allows us, even in this "spectrum" to recommend actions that have the desired military or humanitarian effects. One last example where cultural sensitivities were successfully applied occurred with Gen Douglas MacArthur's handling of Japanese leadership as Supreme Commander of the Allied Powers in post-World War II Japan. Although the Japanese had surrendered unconditionally, MacArthur understood the role of the emperor in Japanese culture and the fact that most of the populace revered the emperor as a deity. Along these lines, he constructed a constitution that established a democratically elected government that preserved the emperor as a figurehead but did not unilaterally strip the emperor of his title. MacArthur's understanding of Japanese cultural norms and his efforts to implement reform while preserving Japanese customs went far in his implementation of one of the most successful post war reconstruction efforts in history."

2.4.10 Anticipatory Observations and Interactive Engagements: "*To facilitate decision making and tempo control by stimulating, eliciting, capturing, and learning from anomalous behavior with emphasis on systems, cultural and behavioral modeling*."

In Section 1 we outlined the overall context of layered sensing, and eventually traced the requirements to the overall AFRL Vision. To Anticipate, Find, Fix, Track, Target, Engage, Assess, Anything, Anywhere, Anytime (AF2T2EA4). This attribute of layered sensing focuses on how we learn to "anticipate". As discussed in 2.4.9, this again means we have to study and learn what behavior in a system (or set of people) is "normal", and what is "abnormal" so we can begin to better anticipate what actions might come next. For systems, the concept is relatively easy to understand. If I prod an enemy's defense radar with a particular Electronic Warfare signal in wartime, how will the radar react? Will it change modes, turn off, or ignore it? Can I use that information later in case I have to negate that radar? By stimulating and prodding a response, I learn something about

how that system behaves. Yet, we have historically been very bad at anticipating actions regarding human or cultural divides. For instance, during the Iranian hostage crisis of 1979, only two employees in the entire State Department could translate Farsi (the Persian language) and neither was in Iran. During the protests the weeks before the Embassy was stormed and sacked, no-one in country could even understand the street protestor's signs and banners. (If they had, the embassy staff would likely have been evacuated months earlier). Although this is a somewhat negative example, a failure to understand the basic anger or decisions from a cultural perspective failed to anticipate problems that lead to the loss of the embassy.

2.4.11 Tailored Performance: "*Sensor and platform selection and employment (to include phenomenology, geometry, and persistence) optimized to scenario (targets, environment, and dynamics) and desired functions (anticipate, detect, track, locate, ID)*".

This attribute is all about the "appropriate" sensor(s) or Sensor "system-of-systems" in the right place and at the right time. If you need the $10M space based camera to peer into denied areas, it is available when and where you need it. If you want to cyber hijack an adversary's cell phone so you can covertly listen in on his phone conversation you place and employ whatever parts of the "layered sensing" architecture are needed to accomplish this. All of the parenthetical options in this attribute are appropriately combined to produce the required data to be processed and acted upon.

2.4.12 Affordable Open System Architecture: "*The Layered Sensing architecture must provide a fiscal and manpower affordable solution set. We believe an inherently "open" architecture will also be cost effective in the long run. Open architecture will be realized by judiciously adapting existing and future joint DoD intelligence and strike systems coupled with leveraged investments in advanced components, sensors, algorithms, and architectural demonstrations of subsystems covering the span of Layered Sensing attributes. Open architecture also presents greater opportunities for enhancing the aggregate capability. While Affordable Open System Architecture may use COTS components, it does not mandate nor require COTS. Open architecture is not just about plugs and sockets. It implies the ability to provide or produce information in formats that are universally readable by the users of information. It also implies that information and situational awareness will be provided in the correct cultural context. This implies we need to exploit open "net-centric architecture" (hardware, algorithm, software) that includes methods of overlaying or inserting the cultural and behavior "layered sensing" construct to information.*

Essentially, this final attribute is a "reality check" on the entire "Layered Sensing" enterprise. The current USAF budget constraints are well understood, and the purpose here is not to blindly advocate for millions of dollars for new spending to implement Layered Sensing. We understand that the USAF has existing ISR and net-centric related capabilities with current systems like Global Hawk, Predator, Rivet Joint, TR-1, AWACs and JSTARS. In addition, the USAF anticipates that its future fighters like the F-35 and F-22 will have extensive sensor system capabilities that can be shared. Our Air Force Chief of Staff has written extensively about needing capabilities where "every shooter is

a sensor", meaning each combat air vehicle can potentially contribute to the global situational awareness enterprise. So, layered sensing must build on these legacy capabilities – we are not starting from ground zero. At the same time, AFRL believes there will be many technology insertion opportunities beyond the traditional "Advanced Technology Demonstration" (ATD) cycle. By innovatively using diverse AFRL assets like Vigilant Eagle, laboratory unmanned aerial systems, and cooperative in-theater technology deployments, AFRL can focus and leverage their technology investments to provide quick, spiral driven upgrades to the layered sensing architecture and components. By paying attention to the "open architecture" standards and implementing demos incorporating these concepts, "plug and play" upgrades become inherently more feasible. In order to accomplish this efficiently, the "Layered Sensing" architecture must be inherently "open". AFRL collectively manages nearly $2.3B in research across all its component technology directorates. Clearly, we believe Layered Sensing will serve as the appropriate catalyst to focus this collective investment.

2.5 Attribute Summary: We have described in a fair amount of detail the meaning of each of the dozen attributes of layered sensing. Since most people have difficulty visualizing a world more complex than our everyday four dimensional world (x,y,z, and time), it is important to understand why the efforts were made to define these attributes. The USAF will be fighting in five dimensions (Land, Sea, Air, Space, Cyberspace) and will employ a "layered sensing-centric" system of system architecture to create situational awareness spanning all dimensions. The commonality of the need for situational awareness for homeland scenarios also demonstrates that the layered sensing construct spans both the military/defense and homeland/humanitarian axes as well. Having described what "Layered Sensing is" through its definition and attributes, we move next to defining how "layered sensing" will be used as a construct for planning the AFRL Sensor research activities.

Section 3.0 –Layered Sensing – A guide for Prioritizing Sensor Investments

3.0 – "Layered Sensing"- Not "Business as Usual" but "Business as Required" to dominate Conventional and Asymmetric Warfare": The whole landscape of intelligence, surveillance and reconnaissance has fundamentally changed with the advent of Irregular Warfare (IW). In the days of the cold war, we knew the enemy, and could read his intentions by the movement of his ships, planes, tanks, and personnel. We could read intentions by who they chose as their leaders, on what they said or didn't say in public. Our ISR job was to track ships, tanks, planes, personnel, and missiles. Today, the environment is totally transformed. We also need to potentially track individual PEOPLE, not just a country's chief executives. We need to track individual cars from source to destination. We need to track cell phone calls, and the physical location of those phone calls. We need to penetrate elusive terrorist cells, and their financial networks. We need to determine intent, within cultural context. We need to read *and anticipate* actions, and this means that we will have to interact with our adversary, as well as his followers and the everyday communications equipment he needs. "Layered Sensing" helps us answer questions as fast as they are asked.

Ubiquitous information is the weapon that will allow us to fight and win asymmetric wars. Who is an insurgent and who is a villager? Which F-15 is fatigued and going to fall apart in flight? Is this a denial of service cyber attack from a high school hack or a Nation State? Is that a piece of trash or an IED by the roadside? Is this category four hurricane going to cause a levy-piercing storm surge? Do I send the National Guard? Is that flour, talcum powder, or something else on that letter?

At first glance, it appears that "layered sensing" is 'business as usual' but with simply more sensors in the environment. After all it was always the AFRL Sensor mission to provide the "commander" with "situational awareness". In fact, a competing definition for layered sensing could have been "*… the AFRL solution to providing all blue forces (man or machine, commander or foot soldier), from all across the kill-chain AIF2T2EA4, with the appropriate situational awareness to improve decision quality. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation algorithms to generate that situation awareness*". In this definition, the "all blue forces" could mean a commander, a first responder, an Information Technologist (IT) administrator, or a pilot flying an aging aircraft. The weakness in this definition is the problem associated with the 'on demand' part. The idea is that our customers want what they want when they want it… not when we can provide it. Thus they often request *tasking authority* of ISR assets – 'on demand', implying that all present and future customers will know exactly what they need in the future. Even further, it assumes the customer can phrase their (ISR) request in terms that will allow the sensor technologist to supply everything we could possibly provide that can help them win their particular fight. We believe that thinking the customer always knows what he will want and need is a bad assumption, and one that routinely gets the USAF in trouble in big weapon system procurements. If one took a brute force approach and wrote/funded

one simple research and development contract to "buy" layered sensing, it would die from the unending list of constantly changing new requirements.

What is needed is *Universal Situational Awareness (USA)*, which brings us back to the AFRL Strategic Plan discussed in Section 1. USA is characterized by on demand information for ALL blue forces at ALL levels of the command hierarchy to help decisions at ALL places in the decision cycle (kill-chain for our war fighters – AIF2T2EA4). Once we understand this, we as technical planners and technology researchers begin to understand that our customers don't all have stars on their shoulders nor do they wear suits (either with a tie or those suits that come in green), nor do they work in an office or behind a green door. We will achieve Universal Situation through the "Layered Sensing definition", of sensors and platforms integrated and exploited and information available for all who need it (man or machine), when they need it, in a form they can use.

Essentially, "Layered Sensing" will help create an architecture system that produces ubiquitous situational awareness. Think of layered sensing situational awareness like electricity in a house – or gas stations along a route – you get what electricity or gas you need when you need it in a form you can immediately use. Even if we could afford to saturate the environment with all types of sensors, all we have done is take lots of measurements. If we allow a given user to task the asset they need (either through a request to us, or giving them control of the asset so they can tell it what to do) we will *never have enough of them* in the right place available for all that want them.

It is AFRL's mission to know what can be sensed in a battle space, and what can be done afterwards to deliver the required effects. It is our mission to ensure that sensor measurements are made *independent of receiving a request* for the measurements. It is our mission to place that information in a form that can be used by anyone, anywhere, anytime to anticipate, detect, distinguish and characterize anything in that battle space and make it available for any blue force element. We also need to keep in mind that some blue force elements are made of silicon versus carbon, which implies there are real "machine to machine issues" we have to step up to.

The challenges that we face to accomplish USA are more than enormous. We need to avoid requiring the users to have to know and understand our detailed ISR technologies. At the same time, we must make USA work without full knowledge of our customer's business or how he uses or may use the data. Neither is completely possible nor practical. They will have missions and needs for data that will be difficult to know or understand until it is exercised in "real world" scenarios. But by knowing our technology business we can architect sensing solutions that are as good as they currently can be and in a way that we can scale them and upgrade them (as sensing improves) and disseminate the information the best as current technology can do and in a manner that will allow us to upgrade and scale the dissemination piece also (as dissemination and exploitation technology improves).

It is business as required in this new fight. Ubiquitous information is the weapon that will allow us to fight asymmetric wars. Layered sensing must be defined and presented as our solution to ubiquitous information from the first responder to the cop on the beat; from the foot soldier to the President of the United States.

3.1 The "Domains" of Layered Sensing - What appears to be self evident in the Persistence Attribute of Layered Sensing is the issue of domain applicability. It is easy to say that "Layered Sensing" applies to Air, Space, and Cyberspace. Remember, the mission of the USAF, is "to *fly and fight in Air, Space and Cyberspace"*. One of the reasons that the layered sensing definition was revisited after its initial introduction in June of 2006 stemmed from the use of one commonly used AFRL Sensor Directorate graphic, shown in Figure 1 below:

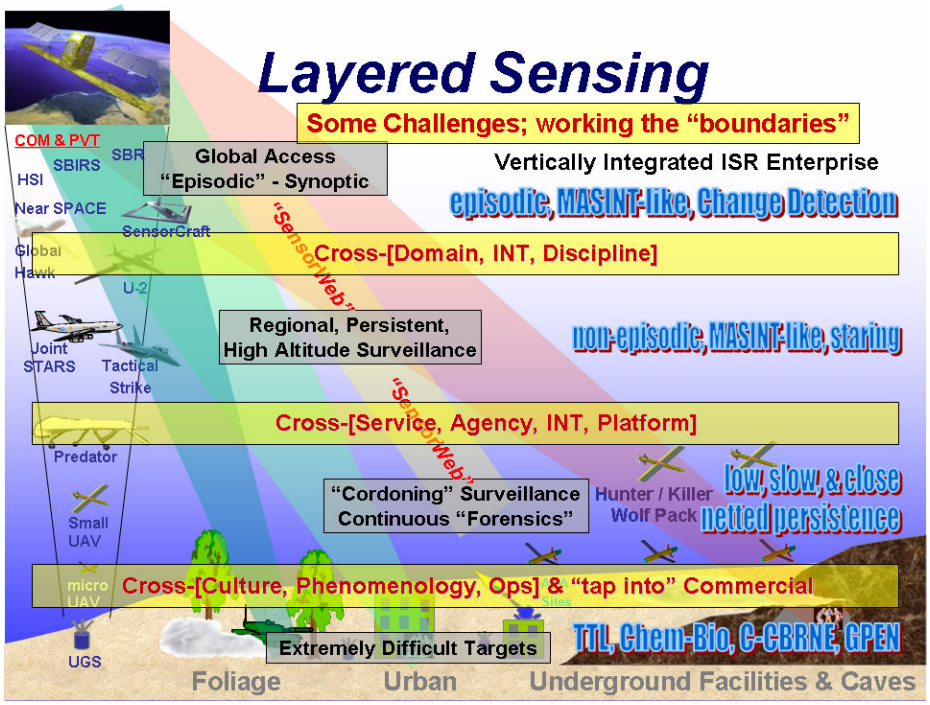

Figure 1 – "Layered Sensing" Graphic (AFRL/RY Directors Call 5-22-07, pp 28)

While this graphic captures many of the features and attributes discussed in Section 2 of layered sensing, looking at the graphic gives one the impression that the layering of assets, from space to ground, gives a decided "Air-to-Ground" ISR-like flavor to the concept. Yet control of the air, or air superiority, is still a fundamental doctrine of the USAF. While we may fight many flavors of Irregular Warfare, we must always be prepared to fight the conventional war with conventional weapons like fighters and bombers. Yet "Layered Sensing", combined with advanced kinetic and non-kinetic weapons will change air-to-air warfare. Keeping in mind our persistent coverage and engagement quality attributes, the scenario shown in Figure 2 is well within the layered sensing construct. A networked, layered sensing architecture passes engagement level information to a hypothetical future JSF equipped with a Directed

Energy laser. This hypothetical JSF then dispatches the adversary fighter without pre-radiating his own radar, thereby making the overall kill silently and stealthily.

Figure 2 – Layered Sensing gives this future JSF engagement level situational awareness to successfully employ Directed Energy weapons for a non-kinetic kill

Cyberspace is even more difficult to conceptualize. On the one hand, we envision a personal computer locking up, or giving us the blue screen of death. Worse yet, it may seem to act normally, when it is spilling the guts of our hard drive to a foreign national's computer. Look at Figure 3. The upper left graphic depicts someone's idea of what cyber war "is" – an image of a weapon watermarked over a PC circuit board. The remaining quadrants of Figure 3 illustrate catastrophic effects enabled by cyber warfare. The upper right is the Pentagon after 9-11, the lower left, Dharan, Saudi Arabia, and the lower right is Belgrade, Yugoslavia. Defeating cyber warfare means we have to detect cyber signatures prior to and during an attack – in the computer networks, or through their emissions of RF, or cellular communications. All these imply unprecedented manipulation of cyber information, on timescales that simulations have shown can take down entire networks in the time it took me to type this sentence.

Finally, the domain of Space, once a sanctuary for the United States, is now contested. In 2007, China successfully launched an Anti-Satellite (ASAT) device and obliterated one of their old weather satellites in orbit. The Geometry of such an encounter is shown in Figure 4, courtesy of MIT-Lincoln Laboratory (http://web.mit.edu/stgs/images/ASAT%20interception.png). According to a recent USAF "AIMPOINTS" article, there are estimated to be over 1500 fragments in this orbit larger than a "softball", representing a huge hazard to navigating this orbit.

Figure 3 – Cyber as a Battlespace. Not just an illusion, but with real consequences

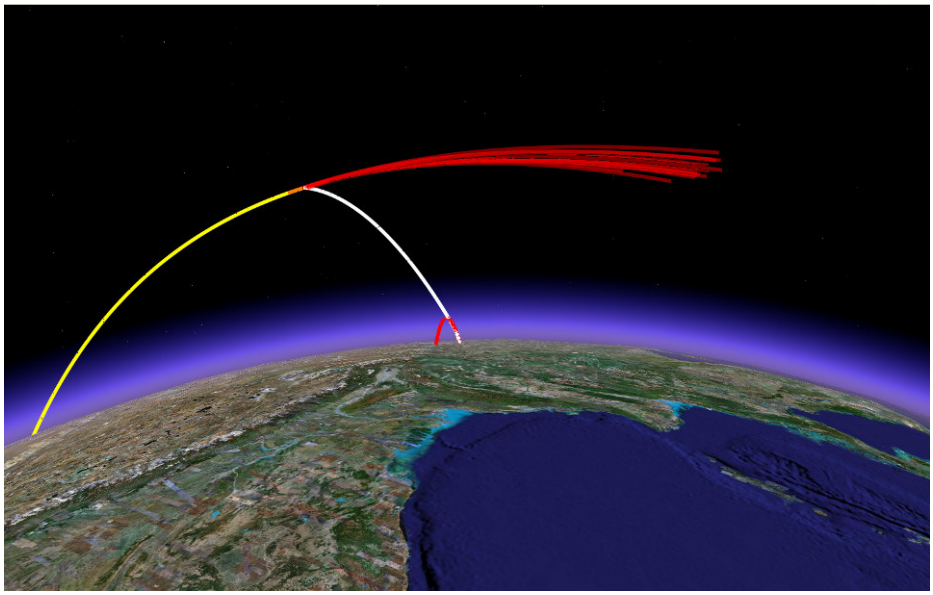
Figure 4 – Chinese ASAT (White) intercepts Weather Satellite (Yellow) producing debris cloud (red).

While we hope to depend on our "space layer" ISR assets to contribute to the layered sensing architecture, part of "layered sensing" must keep track of the threat environment in space. We will need to maintain vigilance over traditional space-based satellites and other "junk" in orbit, via radars like PAVE PAWS in Figure 5.

Figure 5 – UHF Radar for monitoring Space Situational Awareness

In the future, however, we need to worry about adversarial threats that could maneuver very close to our satellites and either monitor or disable them. We must worry about high energy threats directed from the ground or other space based satellites. Certainly, future layered sensing research will have to address the challenge of providing more detailed Space Situational Awareness in the future.

In an overall sense, the graphic for "Layered Sensing" is visually describing a subset of domains that includes ground sensors looking up (staffed and unmanned), elements deployed to support air-ground, air-to-air, the cyber domain, and certainly the near earth space domains.

3.2 Communicating Layered Sensing and its attributes: The "Layered Sensing" construct was created to address two separate audiences. The first issue involved communicating a thorough and commonly understood definition of what Layered Sensing "is", and its attributes down and through the AFRL organizational structure. The second is to thoroughly vet and reexamine our AFRL project and program investment portfolios to assure our planned research activities are aligned with the long term development of the layered sensing architecture and its attributes. Let us spend some time discussing how each of these objectives will be achieved.

3.2.1 Communicating the meaning of "Layered Sensing" internal to AFRL: Effective communication is the key when one attempts to implement any change in any organization. Furthermore, the methods we use to communicate change need to be tailored for inter-AFRL audiences. Our employees will want to know "What is this new approach? Why is it better than what I am doing now? Why do I have to change?" To be effective we need to answer these questions both from the top down and the bottom up. The general vision for "Layered Sensing" has been disseminated in a number of formal forums involving the AFRL/RY Director, including the 2006 AFRL/RY Scientific Advisory Board, May 2007 Directors call, and multiple other venues. The second approach involves "bottom up". The AFRL Layered Sensing Leadership Group (LSLG) combined their collective intellects to reason what "Layered Sensing" means and how it can be implemented through its attributes. This white paper attempts to capture that knowledge and discussion. Next, this white paper must be widely disseminated within the various AFRL Directorates, starting within RY. Every AFRL Engineer, Scientist, and Staff member should read it, and try to

understand and relate how *their* individual project, program, grant, in-house project, test, or support activity adds value to the layered sensing body of attributes and capabilities. If, upon reading this document, our S&E's cannot "connect the dots" between their own body of work and the future "Layered Sensing" attribute space, it is essential that they dialog with their branch and division Technical Experts to either create that connection or redirect their work to align with this new direction. While no-one likes the thought of change, understanding the need for it and the strategic vector we are aligning to should make it easier to adapt new and exciting research and development activities that help AFRL achieve the "Layered Sensing" implementation.

3.2.2 Communicating the meaning of "Layered Sensing" external to AFRL

While AFRL works to unify its own ranks around the concept of "Layered Sensing", the next and possibly most important step is to further communicate how "Layered Sensing" addresses the needs of our various military and civilian constituents. Those constituents run the gamut of Senior Air Force Planners, Program Elements Monitors, MAJCOM's (ACC, AMC, AFMC, SMC) and their respective A2 (Intelligence and Requirements), A4 (Logistics and Sustainment) and A5 (Plans and Programs) staffs. Certainly we cannot leave out our industrial partners (Boeing, Lockheed, Northrop-Grumman, Raytheon), as well as independent big and small businesses that AFRL relies on to execute their research. Finally, we have Congressional staffers, the academic community, other 3-letter agencies, other services, DARPA, and businesses co-residing with and supporting our many AFRL locations. Each of these audiences will require tailored and customized briefings and face-to-face meetings to explain our migration to the "Layered Sensing" construct. To execute this, we must create a ready core of senior technical leaders and planners who were involved in the development of the Layered Sensing definition. A subset of these Scientists and Engineers should be trained and equipped to carry forth and take this visionary technology push to the "outside world" in order to create or add serious and sustained "capability pull" for Layered Sensing. Many of the needs exist now, based on the background discussed previously. The opportunity exists for AFRL to capture and focus our customer's technology needs thereby providing the capital and operational urgency to embark smartly towards a "Layered Sensing" architectural demonstration.

3.3 Aligning the AFRL Core Processes, Core Technical Competencies and Cross Cutting Demonstrations to the "Layered Sensing" Attributes: Under a management reorganization of the research structure delineated in AFRL's Strategic Management Plan [5] , the work executed across the AFRL enterprise falls within three main "core processes". These include S&T Knowledge Generation (Core Process 1 or CP1), Product Development (Core Process 2 or CP2) and Urgent Need Response (Core Process 3 or CP3). CP1 shapes the future Air Force by keeping the technology pipeline full so that we can stay ahead of our adversaries, and bring focus to mid and long term research and development activities (8-20 years.). Customers are senior AF leadership including the Secretary and Chief of Staff. CP2 shapes today's Air Force by addressing the technology needs of acquisition, sustainment and test program managers, and delivering "transitionable" technology products to near

and mid- term programs (2 to 7 years). Customers are acquisition, sustainment and test program managers. CP3 reshapes today's battles by rapidly innovating and bringing together existing technologies to solve urgent warfighter problems (6 to 12 months). Customers are today's deployed forces.

"Layered Sensing" will impact the research in all three Core Processes. While much of the forward looking needs and capabilities will be managed through the AFRL CP1 Core Technical Competencies (CTC's) and Focused Long Term Challenges (FLTC), there are already on-going programs to transition improvements in Layered Sensing Attribute technologies to the warfighter. Within CP3 alone, AFRL is field testing or developing sensor system of systems for combating Helicopter "Brownout" and placing staring visual sensors for persistent city-wide surveillance coverage ("Angel Fire"). Other nearer term CP2 and CP3 demonstrations are in the research pipeline. Figure 5 graphically illustrates the AFRL technology portfolio (from [5]).

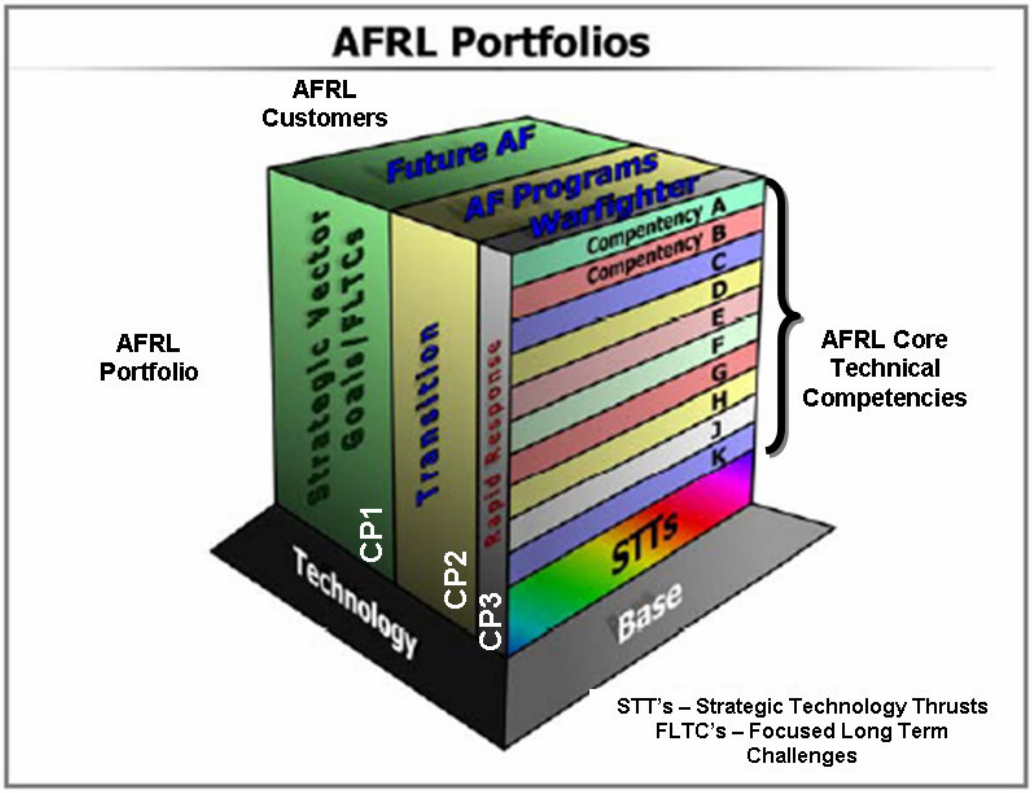

Figure 5 – AFRL Portfolio Investment Breakout (From [5])

Given the nature of Irregular and Cyber Warfare, it is especially essential that CP1 programs and projects be quickly aligned to the "Layered Sensing" attributes. To begin this process, AFRL/RY will execute its first annual comprehensive reviews of their CTC and FLTC portfolios against the "Layered Sensing" attributes in early CY2008. The goal is to examine the content of each CTC to assure that each technical

program and project contributes to the overall "Layered Sensing" architectural development. The RY affected CTC's are shown in Figure 6. In the upper left of this Figure, we see the three unifying strategic vectors from the AFRL Corporate Strategic Plan [3], which also aligns with the recommendations of the 2006 DBS Summer Study [4]. The rightmost column shows the CTC portfolio of AFRL/RY. In the middle is the unifying architectural construct called "Layered Sensing". To assure the CTC's align with the Layered Sensing Attributes, each CTC manager was asked to examine their technical portfolio, right down to the program and project levels. This will include 6.1, 6.2, and 6.3 ATD-like programs, as well as cross-cutting activities like Clean Sweep, Gotcha, Angle Fire, MISPI to name a few. Finally,

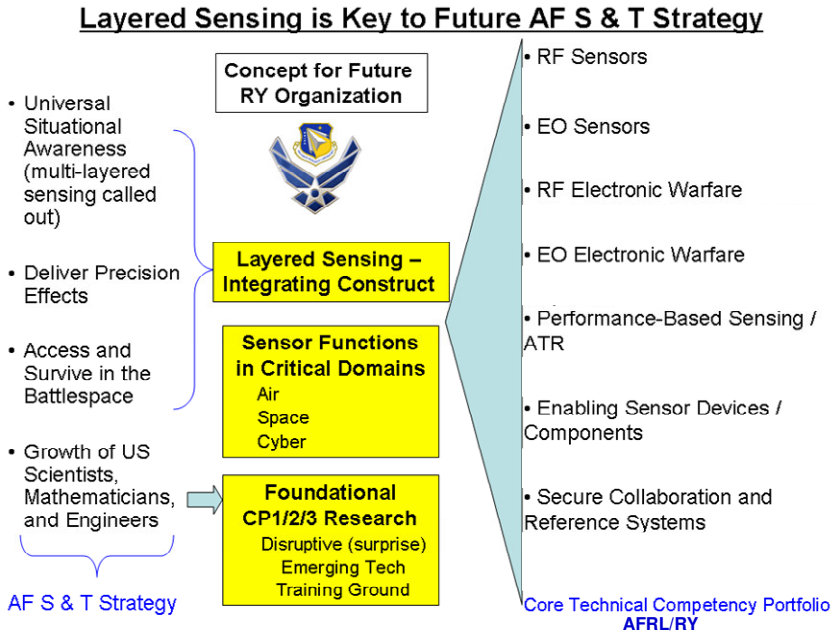

Figure 6 – The AFRL Strategic Planning Vectors Drive "Layered Sensing"

the technical review will include a look at the state of current R&D facilities as well as the facilities that will be absorbed into the RY Dayton location as a result of the BRAC moves from RY (Hanscom AFB) and RY (Rome).

The technical review of the CTC's will be conducted by the AFRL/RY Technology Review Board or TRB. This board will be chaired by the RY Chief Scientist, and consists of the senior technical leaders and senior scientists from both within and outside Sensors Directorate. The review process will consist of an overview from each CTC lead defining the core goals of the CTC, followed by a mapping of the CTC technical programs against the twelve attributes of layered sensing. The TRB will conduct the review using the classic "Heilmeier's Catechism", a series of questions developed by George Heilmeier, Director of DARPA in the mid-1970s, to assess importance and relevance. These include:

- "What are we trying to do?
- What is the problem we are trying to solve?
- How is it done today, and what are the limitations of current practice?
- What is new in our approach, and why do we think it will be successful?
- What gives evidence that it will work?
- Assuming we are successful, what difference does it make?
- How long will it take, how much will it cost, and what are the mid-term and final milestones?

Once the CTC portfolios are complete, the TRB will then review the "Cross-cutting" programs that span multiple directorates and CTC's. Some of the programs to be reviewed include the Universal Situational Awareness Vector Demo, MISPI, Clean Sweep, Gotcha, FLTC-2, parts of FLTC-5 (not included in the CTC reviews), and our interactions with the Space community. In addition, The Base Closure and Realignment (BRAC) team will provide updates on the technical activities associated with the facility moves from Hanscom and Rome AF bases.

The output or product of this TRB CTC review will be used in several ways. First, we will perform a "gap analysis" to determine what portions of the layered sensing attributes are not being adequately studied or researched. This may cause some realignment in the investment portfolios, both within and across CTC's, to better prioritize the research activities. Second, the product will be used as a point of departure to prepare for the Fall 2008 quality review of RY's technical program by the Air Force Scientific Advisory Board.

3.4 Summary: This section provided a quick review of the domains impacted by "Layered Sensing". The concept is much broader than Air-to-Ground, and includes all war fighting domains (Air, Space, Cyber). We covered the importance of establishing a common definition and understanding of "Layered Sensing", and further pointed out that we need to proactively communicate this internally (within AFRL) and externally (AFRL's customers and stakeholders). Lastly, we need to keep focused on the need to decrease our developmental timelines as much as possible on the technologies of Layered Sensing, so that spiral improvements can be fielded as quickly as prudence allows. For this reason, the technology portfolios and cross-cutting programs from the AFRL Directorates must be continuously measured against the "Layered Sensing" attributes.

Section 4.0 – Report Summary

In Section 1 of this document, we began by examining how the nature of warfare has drastically shifted. This nation must face the real possibility of a "near-peer" "Traditional Warfare", all the while worrying about sustained campaigns of "Irregular Warfare". The latter conflicts have utterly changed how the US Armed Forces prosecutes their mission in the defense of the country, since our ability to anticipate, target, and track go down to particular cars, rooms in buildings, and even individual dismounts. While the USAF still needs to be prepared to fight and win a conventional war, the Irregular War is taxing our capabilities to provide the requisite situational awareness to commanders, soldiers, sailors, and airman at all levels. We argued that the new realities of Irregular Warfare drive the need to provide accurate situational awareness to an entirely new level. We then examined the principle missions of the US Air Force, and its R&D arm, the Air Force Research Laboratory. AFRL as an institution, acting on the advice and council from the AF Scientific Advisory and Defense Science Boards, and encouraged by their Chief Technologists and Director of Program and Planning created an AFRL-wide strategic plan which incorporated three key technology investment vectors, (1) *Universal Situational Awareness (USA)*, (2) The *ability to deliver precision effects*, and (3) The *enduring ability to access and survive in the battlespace*. After closely examining various AF Doctrine publications and AFRL's overall strategic planning documents, it is clear that a unifying constructive emerged, and that construct became known as "Layered Sensing". It was first reviewed by the AF Scientific Advisory Board during the Sensors Directorate Biennial Quality review. Their reaction was extremely positive, though they quickly noted that "Layered Sensing" was an AFRL-wide unifying construct. Figure 7 is an AF SAB outbrief chart from the AFRL/SN (now RY) SAB demonstrating this very point.

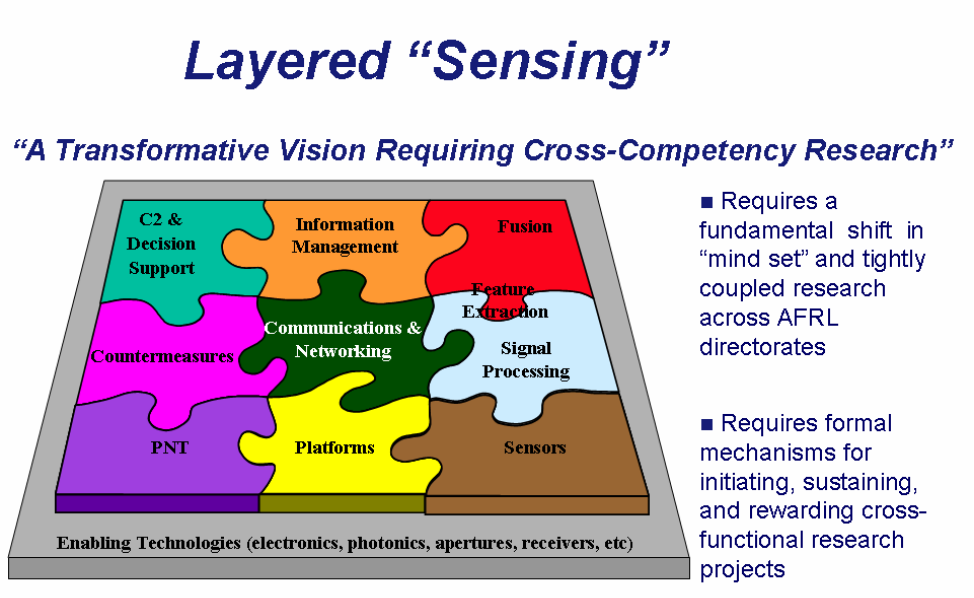

Figure 7 – USAF Scientific Advisory Board 2006 SN Quality Out brief (Slide 6)

It is important that "Layered Sensing" be universally defined and understood. For this reason, the Sensors Directorate sponsored the "Layered Sensing Leadership Group" (LSLG), which defined the term "Layered Sensing" as well as its attributes. This definition is lengthily summarized in Section 2, and summarized in short "executive summary" form in Appendix B. During the intellectual discussions by the LSLG, a telling comment came from Senior Scientist Dr. Steve Rogers -- "Layered Sensing" is *not* "business as usual but *business as required* in this new fight. Ubiquitous information is the weapon that will allow us to fight asymmetric wars. Layered sensing must be defined and presented as our solution to ubiquitous information from the first responder to the cop on the beat; from the foot soldier to the President of the United States". It is our belief that the definition and the attributes provided in this document provide the fundamental anchor by which our technical research activities can be measured against.

Lastly, Section 3 argues that "Layered Sensing" is nearly domain independent in reach and impact. It is not about standard air-to-ground ISR, but non traditional ISR across the board. We need to know what's going on in space, cyberspace, on the ground, in the air, on the high seas, and here in the homeland. Furthermore, we outlined the process by which the AFRL R&D investments, starting with the Sensor's Directorate, must be in total alignment with our Layered Sensing architectural demonstrations. We need to continuously and incrementally improve the attributes associated with layered sensing, and get those improvements to our war fighters or civilian homeland protectors by any means we can, and with all speed.

Our enemy is agile and deadly. Our infrastructure is vulnerable, and our ability to preemptively forestall terrorist threats hangs in the balance. "Layered Sensing" is the key for providing situational awareness that gets there in time to execute options that minimize, deflect, and defeat the threat. The future capabilities of our Air Force depend on our success.

Section 5.0 – References

[1] AF Doctrine 2-3, "Irregular Warfare" dated 1 August 2007, Available from USAF Doctrine Center, or **http://www.fas.org/irp/doddir/usaf/afdd2-3.pdf**

[2] AF Doctrine 2-9, "Intelligence, Surveillance, and Reconnaissance" dated 17 July 2007, available from USAF Doctrine Center, not yet posted on the web.

[3] "Air Force Capabilities Based Science and Technology Strategy 2030", AFRL's Corporate Long Term Strategic Plan, October 2007, Available from AFRL/XP, Wright-Patterson AFB, OH 45433

[4] Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors (Volumes I and II) dated February 2007.

[5] Air Force Strategic Management Plan, September 2007, AFRL's Corporate Long Term Strategic Management Plan Available from AFRL/XP, Wright Patterson, AF Base, Ohio 45433

Appendix A – Layered Sensing Leadership Group Charter (24 September 2007)

Introduction/Purpose of this Charter:

This charter describes the objectives, responsibilities/functions, operating guidelines/processes, linkages, and membership of the RY Layered Sensing Leadership Group (LSLG). The LSLG provides overarching guidance in the development of near and mid term Layered Sensing demonstrations that illustrate the AFRL Layered Sensing vision. This group is formed at the direction of the Sensors Director. The establishment of this group is to provide visionary and supplemental collaboration opportunities to define the future of layered sensing. Note that as the LSLG ideas congeal and specific projects and programs are defined and planned, the technical oversight and execution oversight of these programs shall revert to and continue to be managed by the existing RY Technical Review Board (TRB) and Technical Advisory Group (TAG) respectively.

Objectives for Creation of the LSLG:

The Sensors Directorate created a vision for Layered Sensing that has received support across AFRL and Air Force leadership as well as the Scientific Advisory Board. While there have been a number of research efforts addressing aspects of the Layered Sensing challenge, the LSLG needs to fully define the Layered Sensing Concepts and pull together all related Focused Long Term Challenges (FLTC) and Core Technical Competencies (CTC) efforts into operationally relevant demonstrations to help better define the Layered Sensing architecture for the warfighter. The purpose of the LSLG is to provide this framework for the Sensors Directorate with the goal of collaborating with all relevant AFRL technical directorates that share both an interest in and responsibility for AFRL's execution of Universal Situational Awareness (USA).

The LSLG has the following objectives:

- Help facilitate "corporate" development of Layered Sensing demonstrations with integrated CTC/FLTC activities coordinated across all AFRL directorates.
- Help invent/identify/advocate/plan new layered sensing concepts/demos.
- Help identify partner agencies and sister services to leverage AFRL USA and Layered Sensing funding.
- Engage the warfighting commands to obtain their input and visionary requirements, and regularly advocate Layered Sensing efforts as they evolve.

Responsibilities/Functions of the LSLG:

The LSLG does not replace the role of the Sensors Technical Advisory Group (RY-TAG) or Technology Review Board (RY-TRB). Instead the LSLG acts as an integrating organization to develop Layered Sensing demonstrations and an architecture that builds on past efforts. An initial listing of responsibilities and functions includes:

- Identify and promote operationally relevant demonstrations and a better defined Layered Sensing architecture for the warfighter.
- Develop and maintain a comprehensive technology development investment plan for the Sensors Directorate that includes all contractor-conducted and in-house work units.

- Develop documentation for RY's Layered Sensing technology portfolio—roadmaps, spreadsheets, investment strategy sheets, descriptive summaries, presentation aids, etc.
- Develop processes to achieve "corporate" recommendations to support Layered Sensing demonstrations.
- Provide input to the RY-TAG on new ideas/initiatives with go/no-go criteria for a decision to continue development.

Operating Guidelines/Processes of the LSLG:

As a new group/operation within the Sensors Directorate, operating guidelines and processes will evolve to exploit lessons-learned. Within the context of "getting started," an initial listing of guidelines includes:

- The group will be accountable to the RY Director.
- Members of the group must assure availability of support for group functions on an as-needed basis.
- Group meetings will be both periodic and ad hoc.
- The group may invite participants as necessary from other technical directorates, acquisition offices, functional offices, industry, and others as needed.
- The group may have multiple working groups to accommodate numerous activities within their domain.
- The group will need to develop methods and criteria to prioritize investment opportunities and optimize use of resources.
- The group will rely on the TRB for "technical quality and risk assessments" of proposed and on-going RY programs.

Linkages:

Under the guidance and direction of the RY front office, the LSLG is expected to work closely with the RY-TAG, Planning and Programming Office and all divisions within the directorate.

Membership of the LSLG:

LSLG membership will consist of:

- RY's Core Technical Competency Lead Planners
- FLTC Lead Planner
- 3-Ltr Division level Technical Advisors
- A representative of the financial and procurement functional divisions (RYF and RYK) –non-voting, ad hoc members

If the primary representative is not available to support a LSLG meeting an acceptable proxy may attend to maintain continuity of that organization's participation in the team function.

Appendix B –Summary of Layered Sensing and its Attributes

LAYERED SENSING DEFINITION

"Layered Sensing provides military and homeland security decision makers at all levels with timely, actionable, trusted, and relevant information necessary for situational awareness to ensure their decisions achieve the desired military/humanitarian effects. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of "tailored effects"."

ATTRIBUTES

1. Persistent Coverage: Unblinking eye and omnipresent ears. The ability to provide surveillance and reconnaissance of an area or region in any domain (cyber, air, space) with a revisit rate consistent with mission and information requirements.

2. Wide Area Coverage: A deployable and scalable system that can surveil local/theater/global-level areas of regard and rapidly focus on a specific area(s) of interest with a resolution based on the decision makers information demands while maintaining coverage of the area of regard.

3. Assured Global Access: The capability to access both cooperative and denied areas across all operating domains (including cyber). Elements of the Layered Sensing system of systems in denied domains must be survivable.

4. Engagement Quality Information: Information exploitation provided to the decision maker with the requisite precision, confidence, tracking, context, and where required cross-cueing, to provide him/her with the situational awareness necessary to execute the best decision/course of action. This can range from targeting of a kinetic/non-kinetic weapon to rapid delivery of humanitarian aid.

5. Timeliness: System responsiveness to support quality decision making information early enough in the decision cycle (including the ability to anticipate) to allow the appropriate decision maker adequate time to determine and execute appropriate action.

6. Trusted Sensing: Protocols and systems that establish trust between elements of the Layered Sensing architecture to ensure data is accurate, uncorrupted, and precludes exploitation by adversaries.

7. Information Triage: The efficient identification of the most relevant pieces of information needed by the decision maker out of the volumes of collected data.

8. Robust, Agile and Adaptable: Incorporation of autonomic sensing (self-aware, self-forming, self-healing, self-assessing) characteristics into sensors/networks that allows them to reflexively optimize themselves based on intentional/inadvertent/predicted changes to the sensor/network enterprise/environment. This includes bandwidth capability to support the transfer of information.

9. Spectrum Dominance and Control: Layered Sensing exploits observable quantities in RF, EO, acoustic, chemical, nuclear, biological, cyber, behavioral, and cultural dimensions through overt or covert observations.

10. Affordable Open System Architecture: The Layered Sensing architecture must provide a fiscal and manpower affordable solution set. We believe an inherently "open" architecture will also be cost effective in the long run. Open architecture will be realized by judiciously adapting existing and future joint DoD intelligence and strike systems coupled with leveraged investments in advanced components, sensors, algorithms, and architectural demonstrations of subsystems covering the span of Layered Sensing attributes. Open architecture also presents greater opportunities for enhancing the aggregate capability. But open architecture is not just about plugs and sockets. It implies the ability to provide or produce information in formats that are universally readable by the users of information. It also implies that information and situational awareness will be provided in the correct cultural context. This implies we need to exploit open "net-centric architecture" (hardware, algorithm, software) that includes methods of overlaying or inserting the cultural and behavior "layered sensing" construct to information.

11. Anticipatory Observations and Interactive Engagements: To facilitate decision making and tempo control by stimulating, eliciting, capturing, and learning from anomalous behavior with emphasis on systems, cultural and behavioral modeling.

12. Tailored Performance: Sensor and platform selection and employment (to include phenomenology, geometry, and persistence) optimized to scenario (targets, environment, and dynamics) and desired functions (anticipate, detect, track, locate, ID).